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Selective duodenography for controlled first-pass bolus distention of the duodenum in neonates and young children with bile-stained vomiting

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AIM: To compare "selective duodenograms" performed through nasogastric tubes advanced into the proximal duodenum against traditional contrast studies regarding visualisation of a first-pass bolus distention of the duodenum and frequency of inconclusive results.

MATERIALS AND METHODS: Retrospective comparison of "selective duodenograms" and traditional upper gastrointestinal contrast studies in neonates with bile-stained vomiting, regarding demonstration of the duodenal C-loop, first-pass bolus capture, degree of distention of the duodenum, and number of inconclusive studies. Statistical comparison was performed using the two-tailed Fishers exact and chi-squared tests.

RESULTS: There were 31 "selective duodenograms" and 70 traditional studies. The C-loop was demonstrated in 93% of traditional studies versus 100% in "selective duodenograms" and was demonstrated significantly more often during the first-pass (94% versus 73%; $p=0.018$) and more often with distention of the duodenum for "selective duodenography" (94% versus 56%, $p<0.001$). There were more inconclusive traditional studies (7% versus 3%; non-significant).

CONCLUSION: Emergency upper gastrointestinal tract studies performed in neonates using the "selective duodenogram" technique demonstrated the duodenum with 100% success, with significantly more frequent first-pass bolus visualisation and duodenal distention than traditional studies. The five (7%) inconclusive traditional studies, present a significant diagnostic conundrum in the emergency setting because emergency surgery must be contemplated without proof.

Introduction

Emergency upper gastrointestinal contrast studies (UGIS) are considered the reference standard for diagnosing malrotation/mid-gut volvulus in newborns with bile-stained vomiting.[1] In the emergency setting, these studies can be expedited by introducing contrast medium via an indwelling nasogastric tube, avoiding the necessity for the newborn to swallow the contrast medium and allowing control of contrast medium influx[1,2]; however, introducing the contrast medium into the stomach relinquishes control of the passage of a bolus of contrast medium into the

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duodenum to peristalsis aided by gravity in the right-side-down position. As a natural consequence, there may be trickling of contrast medium into the duodenum in advance of a bolus, inadequate distention of the duodenum with the first pass and jejunal contrast medium overlying the duodenum, all compromising diagnosis (Fig 1). In addition, the use of the right-side-down position despite being considered by many to be diagnostic[3] requires rapid repositioning of the patient for an anteroposterior (AP) view (frontal view), known as the "duodenal roll". In inexperienced hands, this manoeuvre often contributes to patient malpositioning during the important part of the study, and the possibility of a false-positive result[4](Fig 2). As an alternative, contrast medium introduced through a nasogastric tube purposefully advanced to lie in the proximal duodenum allows for performance of a "selective duodenogram" (Fig 3). The timing, pressure, and volume of the contrast medium bolus can be controlled, thereby shortening the procedure, allowing optimisation of the patient position and resulting in distention of the duodenum during a first-pass bolus. This modification of the traditional study is aimed at producing higher-quality diagnostic studies, improving reliability, and resulting in fewer inconclusive results in the emergency scenario, especially for inexperienced radiologists.

The aim of the present study was to determine whether UGIS contrast medium studies performed as "selective duodenograms" demonstrated improved first-pass bolus distention of the duodenum as compared to traditional studies performed with tubes in the stomach, resulting in improved reliability and fewer inconclusive results.

Materials and methods

A retrospective descriptive cross-sectional study, reviewing the most recent 101 UGUS performed in children with suspected malrotation/mid-gut volvulus at one dedicated paediatric radiology department was undertaken. In this department, a portion of the staff complement performs the UGIS using a traditional method of introducing contrast medium through the indwelling nasogastric tube with its tip positioned in the stomach. The remaining portion perform a modified procedure, where the indwelling nasogastric tube is advanced into the second part of the duodenum, allowing for a "selective duodenogram" to be performed, by introducing a 5–10 ml bolus of contrast medium directly into the duodenum, with a pressurised hand-injection. At Bristol Royal Hospital for Children, both procedures are invariably performed with water-soluble, low-osmolar, non-ionic contrast medium.

Patient population

The most recent UGIS performed as emergency procedures in neonates with suspected malrotation/mid-gut volvulus at Bristol Royal Hospital for Children were considered for inclusion and were collected retrospectively, applying inclusion and exclusion criteria, until 101 studies formed the study population. Only those children who had an UGIS performed through an *in situ* nasogastric tube were included. Those children who had had previous general abdominal surgical procedures were excluded. The database was generated from the patient archiving and communications system (PACS) using fluoroscopy study codes and by accessing the reports.

Study design and analysis

Three paediatric radiologists with a cumulative experience in paediatric radiology of over 20 years, reviewed imaging studies spanning a 6-month period, blinded to each other and blinded to the final diagnosis. They recorded identification of the duodenal C-loop; whether the identification of the duodenum was possible during a first-pass

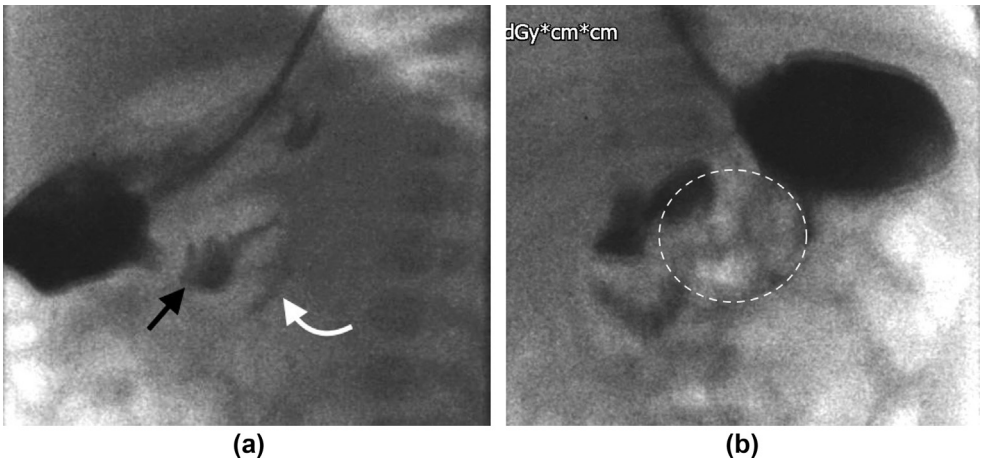

Figure 1 An example of a "poor quality" UGIS in a 6-day-old female patient performed with the traditional method using a nasogastric tube with its tip in the gastric fundus and right lateral positioning. The representative fluoroscopic capture images demonstrate that (a) on the right-side-down lateral view there was trickling of contrast medium (white arrows) in advance of the bolus (black arrow) early in the study (b) resulting in overlapping contrast medium enhanced bowel loops, which prevent definitive identification of the duodenojejunal flexure (broken circle) on the frontal view. The study was considered diagnostic by the operator but not by the study review panel.

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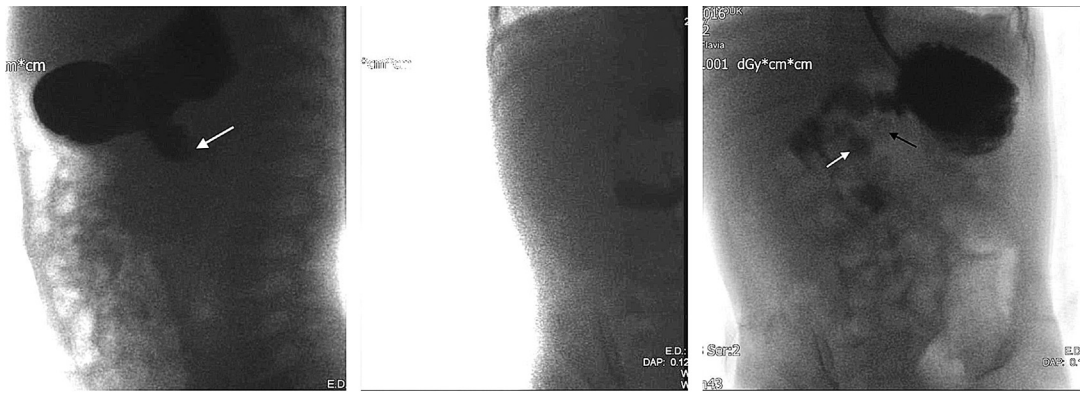

Figure 2 Series of representative fluoroscopic image captures during the "duodenal roll" part of a standard UGIS performed by a junior member of staff in an 8-month-old female patient with bile-stained vomiting. (a) The procedure was commenced with the patient in the right-side-down position to allow gravity to fill the duodenum. The contrast medium bolus is seen entering the first part of the duodenum (arrow). (b) Representative image during the "duodenal roll" into the supine position in an attempt to capture a frontal view of the duodenal C-loop. The radiologist has failed to keep the patient in the field of view during the roll into the supine position and the duodenum is only partially seen. (c) A representative image of the critical portion of the study aimed at demonstrating the duodenal C-loop in the frontal view. During the "duodenal roll" and because of the delay in getting the patient into the field of view, contrast medium has progressed beyond the duodenum and there are now overlapping contrast medium-enhanced loops of jejunum and duodenum. Of note, the patient is also malpositioned and rotated to the right during this image capture, resulting in what was thought to be a false-positive appearance, with the presumed duodenojejunal junction (white arrow) to the right of the right pedicle (black arrow).

bolus or during a subsequent pass; when there was distention of the duodenum during the bolus (first or second pass); a diagnosis of "malrotation/volvulus", "variant of normal", "inconclusive study" (requiring repeating), or a "normal study". A majority decision (at least two of the three readers recording a finding) was taken as the final decision.

Two patient groups were then defined based on the position of the nasogastric tube tip at the time of the procedure: patients with tube tips positioned in the second part of the duodenum, as defined by an inferior course of the distal tube tip beyond the region of the antrum/pylorus (Fig 4) were categorised "selective duodenograms" while all other studies were categorised as "traditional studies". The two groups were compared regarding frequency of each of the imaging findings listed above. Statistical comparison was performed using the two-tailed Fisher's exact and chi-squared tests with significance set at $p<0.05$. In addition,

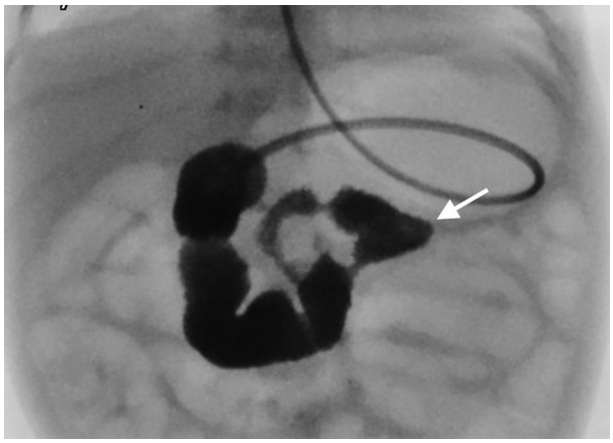

Figure 3 Example of a diagnostic UGIS performed in a 4-day-old male patient using the "selective duodenogram" technique. The contrast medium was introduced through a tube advanced into the duodenum and using a pressurised bolus for distending the duodenal C-loop during the first pass. The study demonstrates the duodenojejunal junction with certainty (arrow) in the normal position.

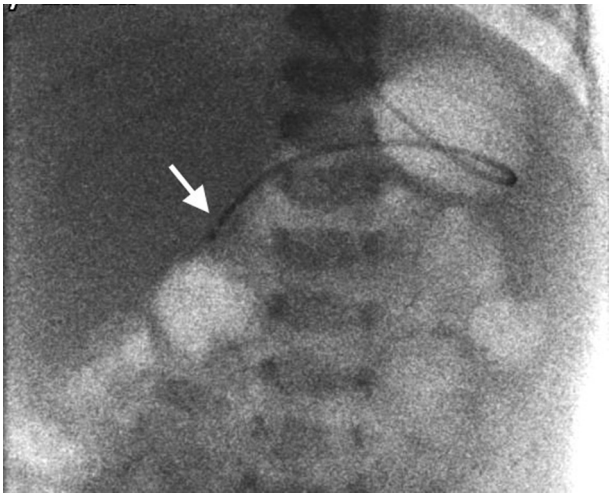

Figure 4 Frontal fluoroscopic image capture during an UGIS in a 2-day-old male patient demonstrating the position of the tube after it was advanced into the duodenum and before introduction of contrast medium. Any upper GI studies demonstrating a nasogastric tube with an inferior course of the tube beyond the stomach (as indicated by the direction of the white arrow in this patient) were considered duodenal, while all others were considered to have a gastric position. This process of categorisation may have unavoidably misallocated some tubes with their tips in the first part of the duodenum (proximal to the inferior bend but external to the stomach lumen) into the gastric category.

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the interobserver agreement was evaluated and compared between groups to determine differences in reliability of the two procedures.

Approval by an ethics committee was not sought because of the retrospective nature of the research using anonymised images and data.

Results

Of the 101 studies, 51 (50%) were in male patients and 50 were in female patients (50%) with a mean age of 81.5 days (range 1–630 days). Thirty-one were performed as "selective duodenograms" and 70 as traditional studies.

Four patients (4%) had malrotation (1 [3%] in the "selective duodenogram" group and 3 [4%] in the traditional group); seven patients (7%) had normal variants (all in the traditional group; 10%), and 84 (83%) were normal (29 [94%] in the "selective duodenogram" group and 55 [79%] in the traditional group).

Overall, six (6%) studies were inconclusive (one [3%] in the duodenal group and five [7%] in the traditional group). This was not a statistically significant difference between the groups. The inconclusive study using the "selective duodenography" was due to erroneous use of diluted contrast medium.

The C-loop was demonstrated in 100% of "selective duodenograms" versus 93% of the traditional group and was demonstrated significantly more often with a first-pass bolus using "selective duodenograms" (94% versus 73%; $p=0.018$) and more often with distention of the duodenum using "selective duodenograms" (94% versus 56%; $p<0.001$). The agreement between observers is summarised in Table 1 and was higher for the "selective duodenogram" group than for the standard method. The Kappa values are considered reflective of the small positive numbers and are not representative.

Discussion

Malrotation of the bowel is potentially life threatening[5] and bile-stained vomiting in a neonate is considered to indicate intestinal obstruction "until proven otherwise".[6] Radiologists are referred to for investigation of the anatomy of the duodenum and identification of features of malrotation and mid-gut volvulus in newborns with this presentation. The radiologist's report directs management in a binary fashion, i.e., patients with normal studies are discharged while those with abnormal duodenal C-loops undergo exploratory laparotomies. False-positive and especially false-negative diagnoses put the neonate under significant risk and cause significant anxiety for the new parents. Inconclusive studies are a significant management conundrum because once contrast medium from an UGIS has progressed into the jejunum, a repeat study can only be performed after some hours' delay, to allow contrast medium to be evacuated and avoid overlapping contrast medium containing small bowel loops.

Optimising the UGIS

The UGIS has long been the recommended test to exclude intestinal malrotation and volvulus.[2,7–9] Although this is widely regarded as the reference standard investigation,[1] procedural limitations make it challenging even for experienced radiologists.[2,10] False-positive and negative upper gastrointestinal studies for malrotation vary and depend on the operator.[11] False-positive rates (resulting in surgery in normal children) of up to 30% and false-negative rates (missed malrotation/midgut volvulus) of up to 6% have been reported.[4,11–13] This has led to a search for alternative investigations, such as ultrasound,[10,11] which have failed to gain sufficient attraction.

The quality of UGIS is critical for it to be considered conclusive and accurate. Yousefzadeh implicates "an element of guessing and uncertainty" in the interpretation of UGIS performed in the traditional manner.[11] Contrast medium that trickles into the duodenum and overlying jejunum prior to duodenal distention by a bolus, compromises the procedure[2] with a possibility of summation of contrast medium from any second-pass bolus, i.e., a duodenal C-loop may be mimicked by superimposed loops appearing to be connected. A reliable, accurate, high-quality examination that can be performed by general and junior radiologists at the point of presentation is needed to obviate the delays and anxiety caused by the urgent referral of patients to the few paediatric centres that offer after-hours consultant services.

Nasogastric tubes are already in use in UGIS to control the influx of contrast medium into the stomach and minimise procedural complications.[2] The right-side-down position is an attempt to direct the passage of contrast medium into the duodenum using gravity, but the lack of operator control mandates active intermittent fluoroscopy and may also result in inadequate distention of the duodenum.

Despite the view of some radiologists that the lateral view of the duodenal C-loop is diagnostic,[3] most radiologists rapidly re-position the patient for a supine view during

Table 1
Inter-reader agreement comparing the standard technique with "selective duodenography" in this study.

Reader combinations	Agreement for standard technique	Agreement for selective duodenograms	Kappa for standard technique	Kappa for selective duodenograms
A versus B	80%	84%	0.53	0.39[a]
A versus C	86%	94%	0.64	0.65[a]
B versus C	89%	90%	0.71	0.54[a]

[a] The kappa was considered inaccurate for the selective duodenograms because of the small numbers.

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passage of the duodenal bolus, (known in North America as the "duodenal roll") [Kraus SJ. Pediatric fluoroscopy: tips and tricks. In *The Society For Pediatric Radiology 2017 Annual Meeting and Categorical Course*, 16–20 May, Vancouver, BC. Reston, VA: The Society for Pediatric Radiology/SPR Research and Education Foundation, 2017]. Andronikou *et al.* previously reported that for non-experts, the "duodenal roll" manoeuvre can result in patient malpositioning in >78% of studies, causing false-positive signs in 48% of UGIS.[4] The "selective duodenogram" allows the operator to distend the duodenum with a controlled, pressurised first-pass bolus of contrast medium, only when the patient is deemed to be in an optimal supine position (Fig 5). Improved diagnostic confidence and accuracy has been argued for by many researchers[2,8,11] and "selective duodenography" provides the means to achieve this.

There were five (7%) inconclusive UGIS in the in the traditional group, where emergency surgery was contemplated without proof of malrotation. The quality of the study determines the confidence with which the duodenum is identified as normal or abnormal, especially for inexperienced operators. Visualisation of a distended duodenum during the first-pass bolus, in a non-rotated patient, with a normally positioned duodenojejunal flexure at or beyond the superimposed left pedicle and at the height of the pylorus,[1,8] is sufficient for determining normality of gut rotation, but relies on the diagnostic quality of the study. Statistically significant quality differences were found between the groups, with the "selective duodenograms" demonstrating the duodenum on first pass and with distention, more often than traditional studies.

Unlike placement of nasojejunal tubes in older children, which require a guidewire for navigating the pylorus because of the J-shape of the stomach, advancing the nasogastric tube in neonates does not require significant manipulation. This is ascribed to the horizontal orientation of the stomach in early life, which retains fetal morphology, lying in both the left and right hypochondrium above the transverse axis passing through the umbilicus[14] and only undergoing growth of the greater curvature with maturity[15] (Fig 6). As such, the passage of the nasogastric tube from the stomach to the duodenum occurs naturally (Electronic Supplementary Material Video S1]. In the authors' experience, the tube spontaneously takes one of two routes: (a) a direct route along the greater curvature of the stomach (Fig 7a) or (b) a reverse left course towards the fundus where it curves to the right to point directly at the pylorus, facilitating entry into the duodenum (Fig 7b).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.crad.2017.12.020.

Neonates presenting to Bristol Royal Hospital for Children with bile-stained vomiting invariably have a nasogastric tube in the stomach. In the event of the neonate arriving without a nasogastric tube, it is recommended that one is placed using the luxury of direct fluoroscopic visualisation.

There are concerns in some quarters regarding distortion of the duodenum by a tube *in situ,* i.e., straightening of the duodenum by a nasojejunal tube and mimicking malrotation.[1] A standard nasogastric tube is recommended, e.g., ENFit (Enteral, GBUK group, North Yorkshire, UK) 6 or 8 F and not a nasojejunal feeding tube, and in addition, that the tip of the tube be placed no further than the second part of the duodenum.

No other causes of neonatal high bowel obstruction were encountered in the present study (e.g., duodenal stenosis/web; hypertrophic pyloric stenosis), but the nasogastric tube will not be able to pass beyond a tight stenosis, and therefore, a duodenal stenosis/web will be adequately outlined. For those keen to demonstrate the stomach (to exclude hiatus hernia or other gastric pathology), the nasogastric tube can be pulled back into the stomach, once the duodenum is demonstrated, and contrast medium can be introduced into the stomach.

"Selective duodenography" for the diagnosis of malrotation/volvulus has the following advantages (Electronic

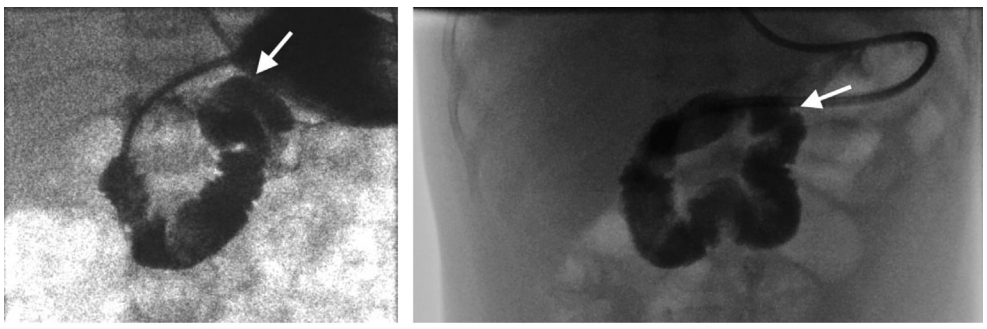

Figure 5 UGIS performed using the "selective duodenogram" technique in two patients of differing age and gender. (a) A 1-day-old male patient with bile-stained vomiting was referred for an UGIS. The operator elected to perform an "selective duodenogram" which demonstrated a normal duodenal C-loop and duodenojejunal junction (arrow) definitively, through distention of the duodenum during a first-pass bolus. This was considered a high-quality diagnostic study and even though there was some reflux of contrast medium into the stomach, this did not obscure visualisation. (b) A 10-month-old female patient with bile-stained vomiting was referred for an UGIS. The operator elected to perform a "selective duodenogram", which demonstrated a redundant duodenal loop with a "W" instead of a "C" configuration, but a normal position of the duodenojejunal flexure (arrow), through distention of the duodenum during the first-pass bolus. There was no reflux of contrast medium into the stomach.

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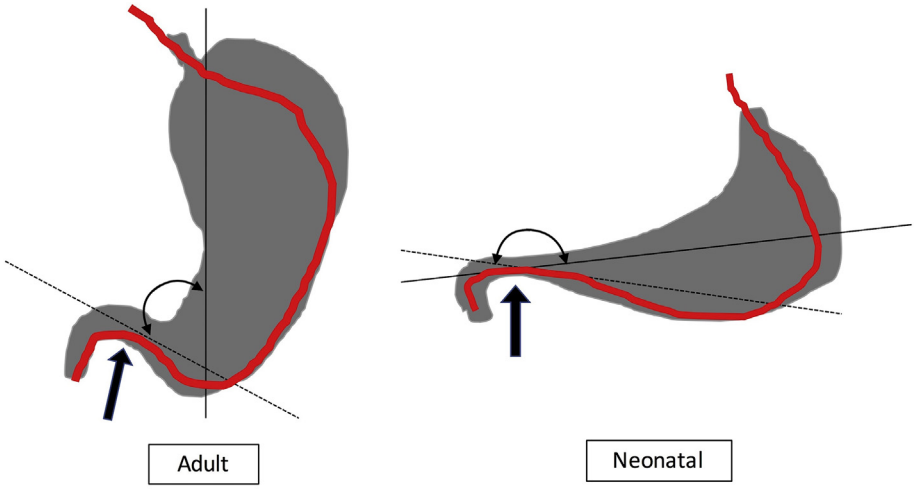

Figure 6 Schematic demonstrating the difference in appearance between an adult stomach from that of a neonate. The adult stomach has a vertical orientation and a "J-shape" with an acute angle between the pyloric channel and the long axis of the stomach, while the neonatal stomach maintains some of its fetal morphology in that its long axis is oriented horizontally and it has an obtuse angle with the pyloric channel. The nasogastric tube is demonstrated by the red line which indicates ideal placement for a "selective duodenography".

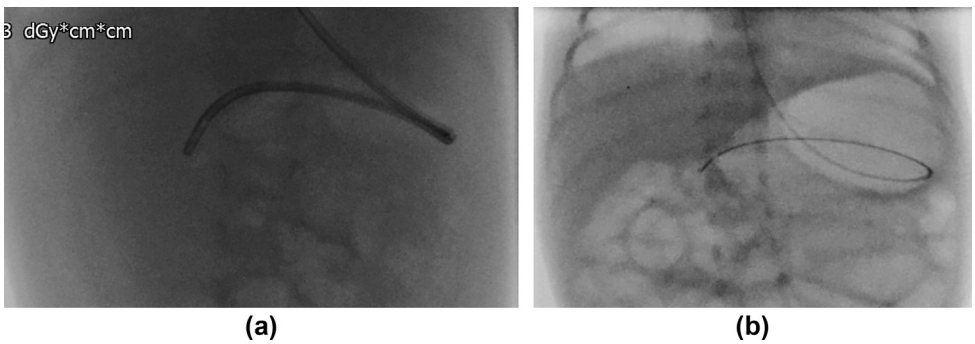

Figure 7 Two different courses taken by nasogastric tubes, which were advanced into the duodenum for "selective duodenography". (a) Tube position for "selective duodenography" in an 8-month-old female patient, demonstrates a direct, horizontal course of the tube along the greater curvature of the stomach, with the tip in the second part of the duodenum. (b) Tube position for "selective duodenography" demonstrating the reverse route for accessing the duodenum in a 4-day-old male patient. On advancing the tube within the stomach, the tube initially courses to the left and then superiorly as it contacts the fundal wall, which results in a loop that directs the tip towards the right and through the pylorus. This reverse course may seem counterintuitive, but is often advantageous for traversing the gastropyloric junction angle.

Supplementary Material Videos S2 and S3): (1) the bolus injection is timed for predictable viewing, image capture, and optimisation of the patient positioning, avoiding false positives due to patient rotation; (2) a pressure bolus allows distention of the duodenum during the first pass without advance trickling of contrast medium, improving quality, and avoiding inconclusive studies; (3) there is no overfilling of the stomach to obscure the duodenojejunal flexure and cause gastro-oesophageal reflux; and (4) there is higher reliability (Fig 8).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.crad.2017.12.020.

Capture of the lateral view for diagnosis, as recommended by Koplewitz and Daneman,[3] is also possible using "selective duodenography" after duodenal placement of the tube in the frontal view. This allows the same advantages of timing and pressure of the "direct duodenography" as for the frontal view. In the lateral position, malrotation is diagnosed when the duodenum turns anteriorly from the junction of the second and third parts, rather than continue in a normal retroperitoneal position.[3] In Bristol Royal Hospital for Children, the lateral position alone is not relied upon because of the possibility of false-negative results (Fig 9).

Limitations

Failure to pass the tube into the second part of the duodenum was not encountered during the study period, but has been encountered subsequently. In such a situation, the operator reverts to the traditional technique. There were only four patients with malrotation, but the primary goal was to publish the technical success of "selective duodenography" in demonstrating the normal C-loop, and for avoiding inconclusive and suboptimal UGIS.

Retrospective review of cine loop captures may fail to account for scenarios where the operator visualised, but did not capture, adequate images of the C-loop. Most studies,

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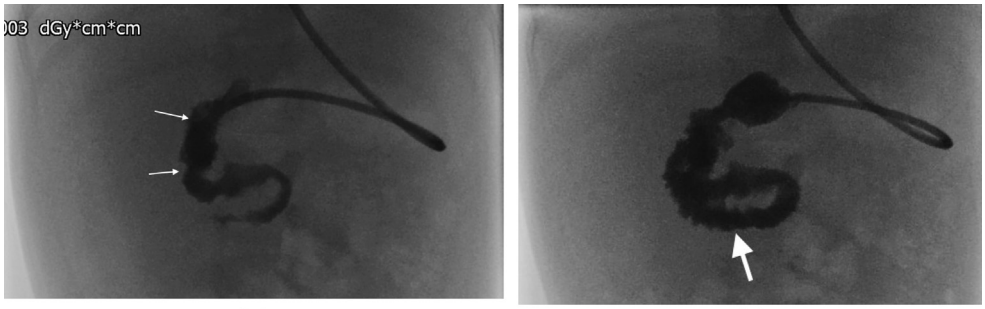

Figure 8 Selected sequential fluoroscopic images captured from a repeat UGIS, in the same 8-month-old female patient as in Fig 2 who had an inconclusive initial study, using the "selective duodenography" method. (a) The first-pass bolus demonstrates the normally oriented first and second parts of the duodenum (arrows). (b) The third part of the duodenum then turns caudally and the fourth part of the duodenum remains on the right (arrow). The position of the dudenojejunal flexure is abnormal. Malrotation was confirmed at surgery where a Ladd's procedure was performed.

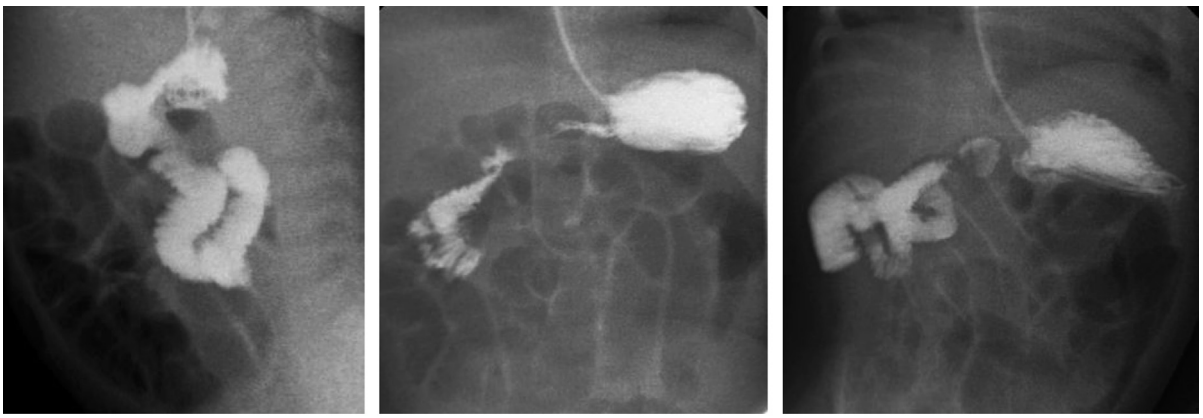

Figure 9 Selected sequential fluoroscopic image captures in a 1-day-old male patient demonstrating the potential for false-negative diagnosis of malrotation on the lateral view, i.e., missing malrotation. (a) Lateral view during the passage of a bolus through the duodenum demonstrates a posterior and presumed normal retroperitoneal position of the second, third, and fourth parts of the duodenum. (b–c) In the supine position the duodenum is clearly abnormal, failing to cross to the left and remaining inferior to the first part of the duodenum. This patient underwent surgery, which confirmed the malrotation.

however, included fluoroscopic cine loop capture of the duodenal roll.

Because of the retrospective nature of this paper, it was not possible to determine if the stomach was aspirated prior to traditional UGIS to prevent dilution of contrast medium.

For both groups in this study it is not known if the patients re-presented later in life with malrotation and midgut volvulus.

In conclusion, emergency UGIS for children with bile-stained vomiting performed using "selective duodenograms" demonstrated the duodenal C-loop in 100% with a 97% rate of conclusive studies. "Selective duodenograms" were of higher quality than traditional studies in demonstrating the duodenal C-loop during the first pass with distention. The 7% of traditional studies that were inconclusive represent a significant diagnostic conundrum in the emergency setting. Therefore the recommendation is for advancing the nasogastric tube into the duodenum under fluoroscopy for "selective duodenography" in neonates with bile-stained vomiting, to achieve high-quality UGIS, minimise inconclusive studies, and improve reliability.

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